UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Electrical Engineering

QUASI-Z-SOURCE INVERTER WITH HYBRID ENERGY STORAGE FOR INDUCTION MOTOR DRIVE SYSTEM

Masitah binti Muhammad

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QUASI-Z-SOURCE INVERTER WITH HYBRID ENERGY STORAGE FOR INDUCTION MOTOR DRIVE SYSTEM

MASITAH BINTI MUHAMMAD

A thesis submitted in fulfilment of the requirements for the degree of Master of Science in Electrical Engineering

Faculty of Electrical Engineering

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DECLARATION

I declare that this thesis entitled "Quasi-Z-Source Inverter with Hybrid Energy Storage for Induction Motor Drive System" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature	:	………………………………
Supervisor Name	:	………………………………
Date	:	………………………………

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DEDICATION

Special Dedication to:

My Beloved Parents,

Muhammad Bin Mat Isa and Rapidah Binti Talib Thank you for your both strong and gentle soul who making who I am today.

My Respected Supervisor,

Dr. Zulhani Bin Rasin

Thank you for your continues guidance and supervised to accomplish this research.

May God bless and protect them with happiness.

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ABSTRACT

The energy storage system (ESS) of many commercially available hybrid electric vehicle (HEV) or pure electric vehicle (EV) is composed of only battery packs with a bidirectional dc-dc converter connected to the high voltage DC bus. In order to further improve fuel consumption efficiency, topologies to hybridize ESSs for EVs and HEVs have been developed. With these various combinations of energy storage, one common feature can be seen; which is to efficiently combine one fast response energy storage device with high power density and slow response device with high energy density. In relation to this, the Quasi Z-source inverter (qZSI) topology has gained attention as an alternative to the conventional voltage source inverter (VSI) in many applications such as the electrical motor drive system. Apart from offering a single stage DC-DC-AC conversion, it offers a flexible way on how the hybrid energy storage (HES) can be introduced to the system. In this research, a new combination of battery/supercapacitor as HES with qZSI applied for the induction motor drive system is investigated. The method of interfacing the supercapacitor via bidirectional dc-dc converter is proposed with implementation of supercapacitor current control to support the battery as the main energy source. The system is designed and modelled together with the required voltage and current control and simulated at 15 kW and 1.1 kW power rating. For validation purpose, hardware experiment at a scaled down 1.1 kW power rating is also carried out. Both simulation and experiment results shows agreement to each other and the proposed method works satisfactorily to reduce the current stress on the battery around 75% at 15kW power rating and around 60% at 1.1kW power rating during acceleration and regenerative braking with overall satisfactory operation of the qZSI fed induction motor drive system. This work has contributes towards efficient hybrid energy storage system for motor drive system not only for the qZSI, but can also be applied for the conventional voltage source inverter (VSI) as well.

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ABSTRAK

Sistem penyimpan tenaga untuk kegunaan pelbagai jenis kenderaan elektrik hibrid atau kenderaan plug-in elektrik komersil yang berada di pasaran terdiri daripada gabungan antara pek bateri dan penukar AT- AT dwi-arah yang disambungkan terus ke AT bas voltan tinggi. Untuk meningkatkan lagi kecekapan penggunaan bahan bakar, topologi untuk menggabungkan pelbagai jenis penyimpan tenaga dalam satu sistem penyimpan tenaga untuk kenderaan elektrik telah dibangunkan. Berdasarkan kepada pemerhatian kepada pelbagai jenis gabungan penyimpan tenaga ini, gabungan di antara penyimpan tenaga yang mempunyai tindak balas yang cekap dengan ketumpatan kuasa yang tinggi dan penyimpan tenaga yang mempunyai tindak balas perlahan dengan ketumpatan tenaga yang tinggi mampu menghasilkan keberkesanan yang baik. Berhubung dengan perkara ini, topologi penyongsang Quasi-Z-Source (qZSI) telah mendapat perhatian sebagai alternatif kepada penyongsang voltan konvensional dalam pelbagai aplikasi seperti sistem pemacu motor elektrik. Selain daripada mampu merealisasikan penukaran AT-AT-AU pada satu tahap, ia menawarkan cara yang fleksibel tentang kaedah untuk mengintegrasikan penyimpanan tenaga hibrid kepada sistem. Di dalam penyelidikan ini, satu gabungan baru bateri/superkapasitor sebagai penyimpan tenaga hibrid untuk qZSI yang diaplikasikan kepada sistem pemacu motor teraruh telah dikaji. Kaedah untuk menyambungkan superkapasitor melalui penukar AT- AT dwi-arah dengan menggunakan kawalan arus sebagai bantuan kepada bateri sebagai sumber tenaga utama telah dicadangkan. Sistem telah direkabentuk dan dimodelkan bersama dengan pengawal voltan dan arus yang diperlukan, dan telah disimulasikan dengan perisian Matlab/Simulink pada aras kuasa 15 kW dan 1.1 kW. Untuk tujuan pengesahan, eksperimen perkakasan juga dijalankan pada aras kuasa 1.1 kW. Keputusan kedua-dua simulasi dan eksperimen menunjukkan kebersamaan dan kaedah yang dicadangkan telah berfungsi seperti diharapkan untuk mengurangkan tekanan arus pada bateri sekitar 75% pada aras kuasa 15kW dan sekitar 60% pada aras kuasa 1.1kW semasa pemecutan dan penyahpecutan dengan keseluruhan sistem pemacu motor teraruh dengan qZSI beroperasi dengan memuaskan. Kajian ini telah menyumbang kepada sistem penyimpan tenaga hibrid yang berkesan untuk sistem pemacu motor, bukan sahaja untuk qZSI tetapi juga boleh diaplikasikan untuk penyongsang konvensional yang lain.

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LIST OF APPENDICES

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LIST OF ABBREVIATIONS

d^r, q^r	-	Real and imaginary of the rotating reference frame
d^e, q^e	-	Real and imaginary of the excitation reference frame
φ^*	-	Flux reference
$\varphi_s{}^*$	-	Stator flux reference
$\varphi_r{}^*$	-	Rotor flux reference
φ_r	-	Rotor flux
φ_s	-	Stator flux
T_e^*	-	Torque reference
T_e	-	Torque
φ_{sd}	-	Direct Stator Flux
φ_{sq}	-	Quadrature Rotor Flux
θ	-	Rotor angle
v_{sd}	-	Direct Stator Voltage
v_{sq}	-	Quadrature Stator Voltage
i_{sd}	-	Direct Stator current
i_{sq}	-	Quadrature Stator current
$S_a^+ S_b^+ S_c^+$	-	Switching Signal a,b,c
ω_r	-	Rotor Speed
V_{dc}	-	Dc-link Voltage
$T_e{}^*$	-	Torque reference
v_{DC}	-	DC voltage
v_C	-	Capacitor voltage
v_L	-	Inductor Voltage
i_a, i_b, i_c	-	Stator current
ω	-	Speed
v_{C1}	-	Capacitor 1 voltage
v_{C2}	-	Capacitor 2 voltage
v_{SC}	-	Supercapacitor Voltage
i_{L1}	-	Inductor 1 current
i_{L2}	-	Inductor 2 current
M	-	Modulation Index

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g	-	Voltage gain
V_{inv}	-	Inverter Output voltage
V_{TRI}	-	Triangular Voltage
$V_{xn,1}$	-	Voltage Inverter Output
V_{ref}	-	Voltage reference
d, q	-	Real and imaginary of the stationary reference frame
EV	-	Electrical vehicles
PHEV	-	Plug-in hybrid electrical vehicle
HEV	-	Hybrid electrical vehicle
ESS	-	Energy storage system
AC	-	Alternating current
DC	-	Direct current
ICE	-	Internal Combustion Engine
SC	-	Supercapacitor
qZSI	-	Quasi-Z-Source Inverter
VSI	-	Voltage source inverter
HES	-	Hybrid energy storage
IM	-	Induction motor
FOC	-	Field oriented control
MSVPWM	-	Modified space vector pulse width modulation
CSI	-	Current source inverter
EMI	-	Electromagnetic interference
ZSI	-	Z-Source inverter
Non-ST	-	Non-shoot through
ST	-	Shoot through
PWM	-	Pulse width modulation
SPWM	-	Sinusoidal pulse width modulation
DCM	-	Discontinuous current mode
CCM	-	Continuous current mode
SL-ZSI	-	Switched inductor Z-Source inverter
SOC	-	State of charge
DTC	-	Direct torque control

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